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PHYSICS.—*The measurement of the refractive index of a drop of liquid.* FRED. EUGENE WRIGHT, Geophysical Laboratory.

Of the many optical characteristics of a substance, the refractive indices are the most important and fundamental, and from them a number of the other optical constants can be derived. In determinative work, moreover, substances are classified and distinguished within narrow limits by their refractive indices. In modern petrographic microscope analysis great emphasis is placed on this optical property, and tables have been prepared in which the minerals are arranged according to the refractive indices. Simple methods are available by means of which the refractive indices of an irregular mineral grain, 0.01 mm. in diameter, can be readily measured with an accuracy of ± 0.001, a degree of precision which is sufficient for all practical purposes. In these methods, liquids of known refractive index are used; finely powdered grains of the mineral are immersed in a liquid and the refractive indices of the grains compared with that of the liquid. For routine work, sets of such liquids are usually prepared by mixing liquids of known refractive index and then measuring the refractive index of the liquid mixture, either on a total refractometer or a spectrometer. In many instances, only a drop or two of the liquid is available, and it is essential that its refractive index be measured accurately. In this paper, the more important methods for this purpose (except those based on the Abbe refractometer) are considered with respect to their accuracy, and ease and range of application,

especially in petrographic microscope work. Several new methods are described; also certain details of manipulation of the standard methods which the writer has found convenient and satisfactory in practice.

Sources of light. For most refractive index work with minerals, the practice among mineralogists has been to use as monochromatic light sources the salts of lithium ($\lambda = 671\mu\mu$), sodium ($\lambda = 589\mu\mu$), and thallium ($\lambda = 535\mu\mu$) in the Bunsen flame. In addition to these the lines of a mercury lamp ($\lambda = 435.8$, 491.6, 546.1, 576.9, $579\mu\mu$) are convenient, especially if used in conjunction with a carbon bisulfide prism or the Wratten ray filters, which isolate effectively the green line, 546.1 (mercury green filter), and also the two yellow lines, 577 and 579 (Wratten E filter No. 22). Other useful light sources are helium and hydrogen tubes and cadmium and iron arcs, but ordinarily the mercury light is a sufficient addition to the salts mentioned.

Uniform illumination from all these light sources can be readily obtained by means of a finely ground glass plate (frosted glass), placed between the source of light and the measuring instrument. The glass plate enables the observer to overcome, without further inconvenience, the ordinary troubles of a flickering flame, which quickly tires the eyes. In this Laboratory, a ground glass plate (25 x 35 cm.), mounted in a simple upright wood frame is placed directly in front of the Meker burners in which the salts are volatilized. The salt is contained in a platinum crucible into which a wick of fine platinum wires extends. This wick carries the melted salt (kept melted by a Meker burner) into the hot flame of a second Meker burner.[1] A hood carries off the vapors and thus shields the instruments from attack by the salts. By this method an intense and lasting flame is produced which burns for hours without further attention. In routine work, too much stress cannot be placed on the satisfactory performance of such details; the above light sources and glass diffusing screen have been proved by long usage in this Laboratory to be convenient and entirely satisfactory.

[1] F. E. Wright, Am. J. Sci. (4), **27**: 195. 1909; **31**: 185. 1911; Carnegie Institution of Washington, Pub. **158**: 88. 1911.

We may now consider the methods for the measurement of the refractive index of a single drop of liquid.

Method 1. A method based on a new type of hollow prism. (Accurate to the fourth decimal place.) This prism (fig. 1) consists of two optically plane parallel glass plates (10 x 20 x 2 mm.) held in place against a 30° glass prism (10 x 10 mm.) by means of a brass clamp (fig. 1). The liquid is introduced between the glass plates and is held in place by capillarity. The semicircular notch in the glass plate (fig. 1) prevents the liquid from creeping up along the ridge formed by the glass plates, and thence into the prism support. The dotted lines in figure 1 indicate the size of the prism of liquid obtainable by this method. It measures over 5 mm. on a side.

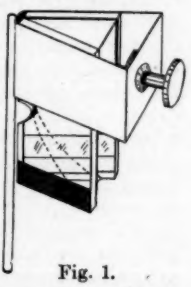

Fig. 1.

With this prism the Abbe method of measurement is used. Autocollimation is obtained by the use of a thin cover glass total reflecting prism[2] in the rear focal plane of the field lens of the telescope of a spectrometer or goniometer. The path of the rays is indicated in figure 2. In order that the reflected rays be as intense as possible the two plates of figure 1 are silvered on the back along a narrow strip 2 mm. wide as indicated by the shaded area on the front glass in figure 1. The measurements are made, after proper adjustment of the prism, by setting first on the normals to the two plates and then on the refracted and reflected beams (fig. 2). In the course of a complete rotation of the prism two readings of the angles i and r (fig. 2) are made.

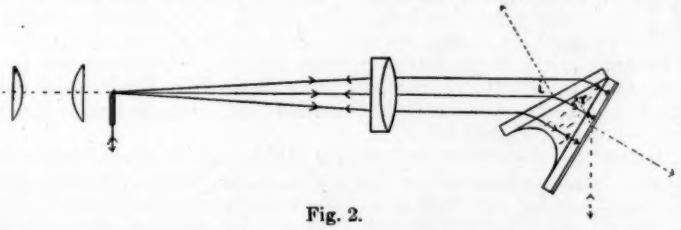

Fig. 2.

The refractive index is then computed directly from the usual equation $n = \frac{\sin i}{\sin r}$. This method is accurate to the fourth decimal place, provided a spectral line source, as mercury, helium or hydrogen light, is used and the circle of the goniometer or spectrometer is accurately divided. The values obtained by this method should be as accurate as any measurements by the standard prism methods with larger quantities of liquid.

[2] F. E. Wright, J. Wash. Acad. Sci., **3**: 234. 1913.

Method 2. The thin plane parallel plates can also be used with a small 60° glass prism (10 x 10 mm.) and the measurements made by the minimum deviation method. In this case both a telescope and a collimator are required. The liquid is held in place by capillarity and prevented from running up along the ridge into the prism support by a notch in the glass plate, as in figure 1. The glass plates are not, however, silvered as in the first method. In this form the prism is somewhat similar in form to the glass prism used first by H. G. Madan[3] for the measurement of the refractive indices of piperine. Madan cemented two thin plane glass plates to the sides of a prism of dense flint glass, allowing the glass plates to project above the top of the glass prism. Into the angle between the glass plates he poured the melted piperine and thus obtained the desired prism of piperine. The same purpose was accomplished later by H. E. Merwin[4] of this laboratory by fusing together at one end two strips of cover glass or object glass under an angle of about 60°. Such strips are not perfectly flat and plane-parallel and the degree of accuracy obtainable by their use is, of course, less than it would be, were plates of better quality used. The cover glass prisms are, however, sufficiently accurate for ordinary purposes and can be prepared in a few minutes.

Method 3. By the use of a small accurately ground 60° glass prism, 5 mm. on a side and 10 mm. long, and three thin plane parallel glass plates (5 x 20 x 2 mm.), a three sided liquid 60° prism can be obtained and the measurements made by the very accurate method which Gifford[5] employed so successfully with large glass prisms.

In the last three methods the regulation of the temperature is not easy but the temperature at which the measurements are made should be carefully noted as a rise of 2° or 3°C. produces an average decrease of 0.001 in the refractive index of a liquid. The refractive index of liquids changes, moreover, on an average 0.001 in refractive index for a change of 6 to 12 $\mu\mu$ change in wave length. Measurements, therefore, even to the fourth decimal place have little significance unless the temperature be accurately recorded and monochromatic spectral line sources be employed.

Method 4. Measurements with the Abbe-Pulfrich crystal total-refractometer (accurate to one or two units in the fourth decimal place). The methods for use with this refractometer are described at length in the standard textbooks and need not be repeated here. Several new details of manipulation, however, which have been found of value, may be recorded briefly. The best readings are made when the light enters at grazing incidence. In this case the field is divided into two halves, the one light, the second dark; the boundary line between the two is so sharp that accurate settings are easily made. With a single drop of liquid, however, this method of grazing incidence has not been applicable heretofore and recourse has been had to the method of total

[3] Jour. of the Chem. Soc. Transactions, **79**: 922–927. 1901.
[4] J. Geol., **20**: 495. 1912.
[5] Proc. Roy. Soc., **70**: 329–340. 1902.

reflection whereby the field is divided into a brightly illuminated half and one slightly less bright. In this case the boundary line is often very difficult to see and accurate settings can rarely be made. If a cover glass be used to cover the drop of liquid, interference bands appear in the field and increase still further the difficulty of making satisfactory settings. These interference bands can be eliminated by tilting the cover glass slip or by grinding its surfaces to a matt velvet finish.

There is, however, a still better method, by means of which the advantages of the method of grazing incidence can be had even on single drop of liquid. To accomplish this a sheet of ordinary thin tin foil, used for wrapping purposes, is first prepared by pressing it with a rubber eraser against a finely ground glass plate. By this process the surface of the tin foil is covered with fine pits, too fine to be distinguished by the unaided eye but relatively large when compared with the wave length of light. If now a drop of liquid be placed on the plane surface of the glass hemisphere of the refractometer and then covered by a sheet (10 x 20 mm.) of the prepared tin foil and monochromatic light be reflected into the hemisphere at an angle less than the critical angle (fig. 3), then the irregular surface of the tin foils reflects and diffracts the light rays back into the glass hemisphere at all possible angles with the result that the effect is strictly that of grazing incidence (light and dark field) and without disturbing interference bands. This method has proved of the greatest assistance in this laboratory in the routine measurement of the refractive indices of liquids.

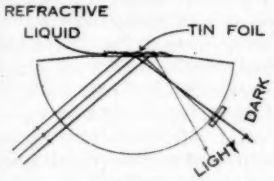

Fig. 3.

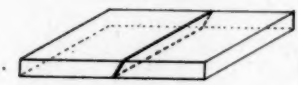

Fig 4.

New petrographic microscope stage refractometers. In many instances petrographers are unable to use the immersion methods for the measurement of the refractive indices of mineral grains, because of the lack of a suitable refractometer and, as a result, neglect such measurements altogether, even though they recognize the importance of quantitative optical work in petrography. In view of this situation, it has seemed to me worth while to try to devise a simple method for use with the petrographic microscope by means of which the refractive index of any liquid can be measured with an accuracy of ± 0.001, which is adequate for ordinary determinative purposes. A number of such methods are suggested below and with one or two exceptions, are based on the fact that the petrographic microscope, equipped with the usual Bertrand lens and a micrometer eye-piece, is a device for measuring the angle of inclination of an incident ray (as in the measurement of of the optic axial angle); and, furthermore, that its sensitiveness to

slight angular differences in inclination between incident rays increases with the focal length of the objective used.

Method 5. For this method a plane-parallel plate of highly refracting lead glass ($n_N^a = 1.92$) with one plane polished and one plane matt finished edge inclined at an angle of 60° is required. This plate (20 x 20 x 4 mm.) after grinding is cut into two halves at right angles to the beveled edge (fig. 4). The two halves are then placed in contact with the polished edge of the one half above the matt ground edge of the second half. A drop of liquid between the two plates is held in place by capillarity and its refractive index ascertained by observing the position (16 mm. objective, Bertrand lens, positive eye-piece with micrometer scale) of the limiting refracted ray between the light and dark fields as indicated in figure 5. This limit between the light and dark halves of the field is sharply imaged in the plane of the micrometer scale by means of which its position can be read off directly.

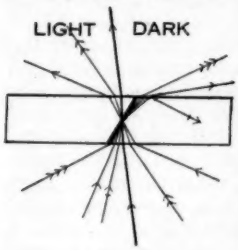

Fig. 5.

The scale is calibrated empirically once for all by the use of substances of known refractive index. Three substances, which can be had in powder form and which melt at low temperatures, can be used for calibration purposes because of constancy of refractive index for sodium light; they are "Kollolith, $n_{Na} = 1.5354$; benzophenon, $n_{Na} = 1.598$ and piperine, $n_{Na} = 1.682$. Liquids of known refractivity can also be used but, unless controlled by measurements on a refractometer, the refractive indices of commercial liquids are not sufficiently uniform to serve as calibration standards. After the scale has been calibrated and the points plotted, a curve can be passed through the observed points, as indicated in figure 6, which represents the values actually observed by the writer on liquids of known refractivity. The curve is a small part of a simple sine curve and is sufficiently accurate for refractive index determinations to the third decimal place. The measurements were made with a 16 mm. Zeiss apochromat objective, Bertrand lens and 0.1 mm. coördinate scale in the focal plane of a positive eye-piece. One-quarter of a division of the scale could be easily read and was equivalent to 0.001 in refractive index. With a higher power eye-piece or a moving micrometer eye-piece still more accurate readings can be made and more

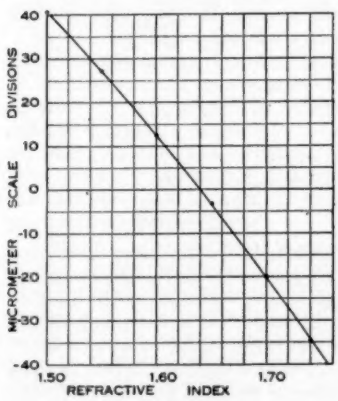

Fig. 6.

precise refractive index determinations obtained, but for most purposes the third decimal place is sufficiently exact. Still greater accuracy can be had by using plates of different refractive index, the beveled edges of which are so cut as to give the greatest sensibility to slight differences in angular inclination. In this case a lower power objective can be used and, if necessary, one or two units in the fourth decimal place obtained. The phenomena of total reflection take place at the surface of the upper plate as illustrated in figure 5. It is not essential, therefore, that the second glass plate be of the same refractivity as the first. The disturbing interference fringes, caused by internal reflection, are eliminated either by making the slope of the beveled edge of the lower plate different from that of the upper or by grinding it to a matt finish. This method is simple in principle, easy to apply and sufficiently accurate for most purposes.

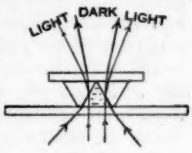

Fig. 7.

Method 6. This method is a variation of method 5. A prism of liquid is formed between a plane-parallel base plate and two small prisms of lead glass cemented to a thin plane-parallel glass plate. The path of the rays is shown in figure 7. The method of measurement is identical with that of method 5 except that here the distance between two boundary lines is taken instead of the distance of one boundary line from the center. The accuracy of this method is not appreciably greater than that of method 5; it is, moreover, less convenient to apply and, to that extent, less satisfactory.

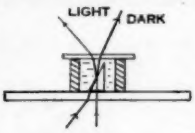

Fig. 8.

Method 7. This method is similar in principle to 5 but instead of a prism of refractive index higher than that of the liquid a prism of lower refractivity is used. A prism of fluorite ($n = 1.434$) or of silica glass ($n = 1.459$) is cut so that the inclined edge includes an angle of 65° with the horizontal face (fig. 8). The prism is placed on a small glass plate (plate glass) inside a small brass ring cemented with shellac to the glass plate. This ring is then filled to the top with a few drops of the liquid and covered with a thin plane-parallel plate. The path of the rays is indicated in figure 8. By the use of glass prisms of different refractive indices and slopes, it is possible to obtain determinations accurate to one or two units in the fourth decimal place. Ordinarily, however, with a 65° prism of fluorite it is possible to measure the refractive indices of all liquids ranging in refractive index 1.45 to 1.80 with an accuracy of ±0.001. This method requires more liquid than method 5 and is less convenient to use because of the bother of cleaning the liquid from the prism and the brass ring.

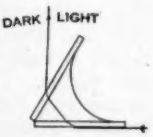

Fig. 9.

Method 8. This method involves the use of the hollow prism of method 2. Light is admitted as indicated in figure 9 and the inclination of the emergent ray is ascertained as in method 5. This method is comparable in accuracy to 5 but it is not always easy to apply be-

cause of the wide angled prisms which are required (between 70 and 80°). It is, however, less convenient than method 5, especially as the liquid in the flat lying prism tends to spread and to smear the glass plates and prism as well. For a range of refractive indices 1.50 to 1.75 at least two such prisms are necessary unless the prism be mounted on another prism so that its lower surface is inclined at an angle with the horizontal. Thus a 60° prism of liquid is obtained by grinding the one face of the prism at an inclination of +22°, and the second face at −38° with the horizontal base. The inclination of the emergent ray for a liquid of refractive index 1.50 is then +10° 06′, while for a liquid of refractive index 1.75 it is −10° 03′. Under these conditions the accuracy is identical with that of method 5, namely ±0.001. Although this method is less simple than method 5, it is theoretically superior to it in one respect; namely, it is free from any error introduced by the dispersion of the glass prism; practically this is of no significance because the refractive indices of the glass prism are definitely known for the different wave lengths.

Method 9. The device on which this method is based is illustrated in figure 10. It consists of a thick glass plate with one edge beveled by two flat surfaces, the one inclined 25°, the second at 60° to the horizontal base (fig. 11). A plane parallel glass plate (8 x 15 x 1 mm.)

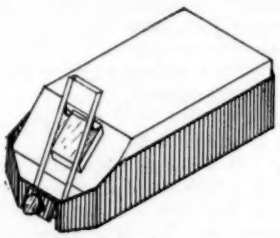

Fig. 10.

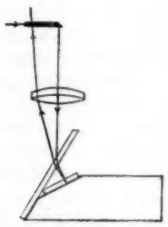

Fig. 11.

is clamped to the 60° surface by a screw clamp; while on the 25° surface a plane-parallel plate (6 x 8 x 1 mm. and silvered on the back) rests with its edge in contact with the first plate (fig. 10). A drop of liquid is held by capillarity in place as a liquid prism between the two plates. The rays from a thin total-reflecting cover glass prism[6] in the rear focal plane of a 16 mm. objective are reflected, after refraction in the liquid, back into the objective where the illuminated line image of the cover glass prism edge is viewed simultaneously with the prism edge, through a Bertrand lens and positive eye piece fitted with the micrometer scale as described in method 5. The exact position of the bright line is read off directly on the micrometer scale and thus the refractive index of the liquid ascertained for the particular wave length of light employed. As in the fore-

[6] J. Wash. Acad. Sci., **3**: 234. 1913.

going methods the micrometer scale is first calibrated by means of liquids of known refractive indices. This method is slightly more accurate than method 5 but it is less convenient and requires considerably more apparatus. It is, however, not encumbered with an error, due to the dispersion of the glass.

I have also tried to apply the method of total reflection on a single inclined edge of a plate of lead glass, in imitation of the method noted in method 4 but the phenomena obtained were too faint and indistinct to be of service and no satisfactory measurements were made.

Method 10. Methods of Clerici and Viola.[7] These are based on the difference in refraction between a liquid and a small submerged glass prism (fig. 12). They are noted here simply for the sake of completeness and do not compare in accuracy with the new methods 5 to 9 described above. I have tested Clerici's methods and also Viola's modification of the same and verified Clerici's statement that his methods are accurate to ± 0.005, while Viola's modification is possibly slightly more accurate, namely ± 0.004. The methods are simple and easy to apply. An improvement is to use a set of fluorite or silica glass prisms (low dispersion), cut at such angles that a large deviation is obtained for slight differences in refractive index, each prism to be cemented above a 0.1 mm. scale.

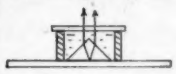

Fig. 12

Method 11. Method of Piltschikow.[8] This method is based on the focal length of a lens system, one of the components of which is the liquid whose refractive index is to be measured. The liquid is introduced into a hollow plano convex lens and the focal length of the combination measured. To increase the accuracy of setting on the exact focus only the marginal zone is used. This method requires monochromatic light and under favorable conditions should be fairly accurate. Modifications of this method were suggested by Smith[9] and Clay.[10] The writer has not had opportunity personally to test the method of Piltschikow but it is evidently less simple and accurate than method 5 described above.

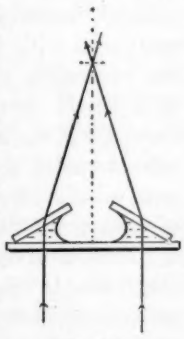

Fig. 13.

Method 12. Similar results can be obtained by the use of two hollow prisms as indicated in figure 13 or by means of a lead glass plate with two beveled edges (fig. 14). An incident beam of parallel monochromatic light and two narrow slits placed symmetrically with respect to the two prisms are required. The focus is then the line of intersection of the two refracted beams. The distance of this focus

[7] E. Clerici, Atti della Reale Academia dei Lincei, Roma, **16**: 1, 336–343. 1907; **18**: 1, 351–355. 1909; C. Viola, Ibid., **19**: 1, 192–197. 1910.

[8] J. Russ. Chem. Soc., **13**: 393. 1881.

[9] Amer. Mon. Microsc. Jour., **6**: 181–182. 1885.

[10] Treatise on Practical Light. London, 143. 1911.

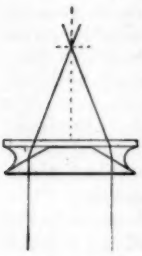

Fig. 14.

from the prisms varies with the refractive index. Its position can be fixed by means of a scale on the side of the draw tube of the microscope. For two prisms of angle 15° the variation in distance between the focal points for liquid of refractive index 1.50 to one of index 1.75 is 25.0 mm. If it were possible to focus sharply to 0.01 mm. on the indistinct bands of light, the probable error would be ±0.001 but this is not the case. The bands of light are not sharp and the exact point of central overlap is not easy to recognize. At best one might obtain the second decimal place by this method which is not satisfactory and neither the hollow prism nor the glass plate method of this paragraph are to be recommended.

SUMMARY

The refractive index is the most important optical constant with which the petrographer has to do, since its determination on a single mineral grain enables him practically to identify the mineral within narrow limits. The determination of the refractive indices of irregular mineral grains measuring 0.01 mm. in diameter is best accomplished by means of the immersion method, in which the refractive indices of the mineral grain are compared with that of the liquid in which it is immersed. In the preceding pages the measurement of the refractive index of a single drop of liquid is considered in some detail. The accuracy of the standard methods (with the exception of the Abbe refractometer methods) for this purpose is discussed and certain new modifications are suggested which render the application of such methods to a single drop of liquid possible. The use of a diffusing screen in front of monochromatic light sources is emphasized. A new type of hollow prism is suggested which has proved satisfactory and convenient, and with which accurate measurements (accurate to the fourth decimal place) can be made either by a method of autocollimation or by the minimum deviation method or by Gifford's method. The use of a cover of specially prepared tin foil on a drop of liquid to be measured on the Abbe-Pulfrich crystal total-refractometer is suggested as a satisfactory method for obtaining the phenomena of grazing incidence even on a thin film of liquid. Five new methods are also described for measuring the refractive index of a drop of

liquid with the petrographic microscope. Of these methods, method 5 which requires solely a plane-parallel glass plate of high refractive index, with one edge beveled at an angle of 60°, is the simplest and most convenient. With it the refractive index of the liquid can be easily measured to the third decimal place, an accuracy which is sufficient for all determinative purposes. The other methods are interesting and of about the same order of accuracy but they are less simple and therefore less useful. The methods of Clerici, Viola, Piltschikow, Smith and Clay are presented briefly but they are also without exception less simple and less accurate than method 5, which is accordingly the method recommended, especially as the cost of the glass plate required is slight and the amount of liquid necessary for a measurement is a very small drop. It is of the greatest importance to the science of petrology that the materials, of which it treats, be studied in a quantitative way; the refractive indices of the rock making minerals, many of which are isomorphous mixtures, are fundamental optical constants which should be measured and included in every detailed description of a rock.

PHYSICS.—*The emissivity of metals and oxides. I. Nickel oxide (NiO) in the range 600 to 1300°C.* G. K. BURGESS and P. D. FOOTE. (To appear in full in the Bulletin of the Bureau of Standards.)

The object of the present investigation has been the determination of the monochromatic (E_λ) and total emissivity (E) of nickel oxide (NiO) in the range 600 to 1300°C. This oxide forms a tough, smooth layer on the surface of nickel when subjected to high temperatures in air. Two methods were employed for the determination of the emissivity for red light: (a) that of microscopic melts, and (b) a direct comparison by a spectrophotometer of the intensity of light emitted by the glowing NiO and by a black body at the same temperature.

In the method of microscopic melts, minute specimens of NaCl, Na_2SO_4, and Au were placed on the oxide which was electrically heated until these substances melted, as observed with a microscope, and the "apparent" temperatures at the instant

of melting were observed with an optical pyrometer. Hence, from the true and the apparent temperatures of the oxide, the emissivity can be computed.

In the spectrophotometric method, a nickel strip was folded, forming a wedge- or V-shaped cavity, and electrically heated until a coat of the oxide was formed. It has been shown by Mendenhall that the radiation from the interior of a V-shaped cavity is "black." The ratio of the intensities of the outside and inside of the wedge, properly corrected for temperature gradient through the walls, gives at once the emissivity at any particular wave length and temperature. Determinations by this method agreed with those by the method of microscopic melts. The monochromatic emissivity was found to increase linearly with increasing wave length from $\lambda = 0.5$ to 0.7μ and decrease linearly with increasing temperature from 700 to 1300°C. For example, at 1160°C, E_λ increases from 0.86_5 at 0.5μ to 0.88_2 at 0.7μ; and for $\lambda = 0.65\mu$, E_λ decreases from 0.95_8 at 800°C. to 0.84_5 at 1300°C.

The total radiation of NiO was investigated by means of twelve radiation pyrometers of the Thwing and Féry types, sighted upon the electrically heated oxide. The apparent temperature of the oxide for $\lambda = 0.65\mu$ was measured by an optical pyrometer and these values were corrected to true temperatures by means of the determinations on the monochromatic emissivity. E was found to increase with increasing temperature but the relation is not linear. Temperatures and E have respectively values as follows: 600°, 0.54; 800°, 0.68; 1000°, 0.76; 1200°, 0.85; 1300°, 0.87. Correction tables are required for reducing the apparent temperatures of NiO, observed with an optical or radiation pyrometer, to true temperatures.

PHYSICS.—*Flame standards in photometry.* E. B. ROSA and E. C. CRITTENDEN. (To appear in full in the Bulletin of the Bureau of Standards.)

Although an agreement has been reached regarding the relative values of the units of light in use in different countries, no one primary photometric standard has been generally

adopted by the various governments. In Germany preference is given to the Hefner lamp, in England to the pentane lamp, and in France to the Carcel lamp. Each of these serves in its own country both as the primary standard and as a working standard, but for the photometry of electric lamps and generally in accurate photometric work standardized electric incandescent lamps are used in all countries. In America a group of such lamps kept at the Bureau of Standards is considered as provisional primary standards serving to maintain the unit until a better primary standard shall have been devised. It is believed that the unit which has been agreed upon can be so maintained with an accuracy considerably above that with which it can be reproduced by reference to any of the so-called reproducible standards at present in use. In other words, the incandescent lamps have really been employed as primary standards, and the flame standards, which logically should play the part of primary standards, have been relegated to a subordinate position.

There is, however, a possibility of an appreciable drift in the value of the unit if there is no photometric standard accurately reproducible from its specifications which is capable of serving as a reliable check upon the electric standards. It has therefore appeared worth while to make a study of the best types of flame lamps to see how closely they would reproduce, in the Bureau laboratory, the values adopted by international agreement and also to find whether their reliability as primary standards could be increased by any changes in construction or in operation.

The Carcel lamp is by far the least reliable of the three types, and cannot be considered as a competitor for general acceptance. The Hefner and the pentane lamp as made at present divide honors; the latter is markedly superior as a practical standard, but individual pentane lamps do not agree, and until lamps can be independently made which shall give the same value the type can hardly be said to be reproducible. The Hefner lamp is so simple in construction that reproduction of lamps is relatively easy. Lamps now made show small differences due to slight departures from mean dimensions, but these differences can be made negligible by more careful

construction. Great difficulty is experienced, however, in making accurate comparisons of working standards against Hefner lamps because of the very low intensity (0.9 candle) and the red color of the flame.

It is believed to be possible to apply the principle of the present pentane lamp in specially made, accurately specified lamps with interchangeable parts, and thus to obtain a closer agreement between lamps. Then by operating the lamps under definite conditions one should be able to obtain sufficient precision with either the Hefner or the pentane lamp to give a valuable check on the electric standards now in use.

PHYSICAL CHEMISTRY.—*A thermoelectric method for the determination of the purity of platinum ware.* G. K. BURGESS and P. D. SALE, Bureau of Standards.[1]

At the request of Dr. W. F. Hillebrand, Chairman of the Committee on Quality of Platinum Utensils of the American Chemical Society, experiments on the loss in weight due to continued and repeated heating of platinum crucibles of varying degrees of purity have been undertaken, in continuation of similar experiments carried out under the immediate supervision of members of the above-mentioned committee.

From some of these earlier experiments, and from the work of other experimenters on the evaporation of metals of the platinum group, it appears to have been hoped to be able to classify platinum ware as to purity in terms of its evaporation at a definite temperature, say 1200°C. This seemed plausible in view of the fact that the usually predominant impurity, iridium, is very much more volatile than platinum. Even if this method, however, would give an indication of the platinum purity, which appears doubtful in the light of some of our more recent experiments, it is at best a somewhat tedious and delicate operation to carry out.

These experiments showed the desirability of having an accurate and rapid method for determining platinum purity and one that could be applied to crucibles without defacing them.

[1] Presented at American Chemical Society, April 6, 1914.

The most exact method for the determination of purity of platinum appears to be by measurement of its temperature coefficient of electrical resistance, which quantity has a mean value of about 0.00391 per degree Centigrade for the interval 0° to 100°C. for the purest obtainable platinum, and decreases with the addition of anything to the platinum. This measurement can be made conveniently and exactly only with wires and is therefore of little interest for the determination of the purity of platinum ware such as crucibles.

The thermoelectromotive force of platinum against many of its alloys has also been determined with considerable exactness.[2]

This property may evidently be made use of, therefore, in devising a method for the determination of platinum purity and one that possesses, furthermore, the advantages of accuracy, speed, convenience, and preservation intact of the objects tested.

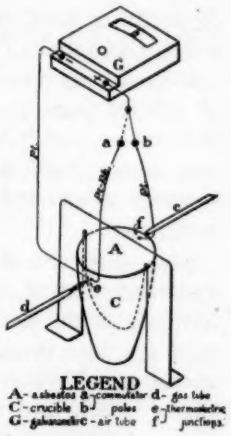

Fig. 1.

The method as developed for use with crucibles is shown in figure 1. To the rim of the crucible *C* are arc-soldered two *pure* platinum wires, at *e* and *f*, of small diameter (0.1 or 0.2 mm.); these wires are connected to an ordinary pyrometer galvanometer or millivoltmeter *G*; the junction *e* is heated by a small oxy-gas or other blast flame from *d* and the junction *f* is kept cool by an air blast *c*; a sheet of asbestos *A*, cut as shown, serves to prevent radiation from the heated portion of the crucible reaching the cold junction *f*.

Temperatures are measured by means of a 90 Pt – 10 Rh, Pt thermocouple using the cold junction as above and a Pt – Rh wire arc-soldered to the crucible near *c*, most conveniently adjacent to (0.5 to 1 mm. distance) but not touching the Pt wire at *e*.

[2] See in particular: W. Geibel, Zs. Anorg. Ch. **69**: 38. 1910; **70**: 240. 1911; Burgess and LeChatelier, The Measurement of High Temperatures, 3d ed. 171, 1912.

Quite satisfactory results may also be obtained by simply touching the Pt wires to the crucibles at *e* and *f* without any soldering. With the apparatus once set up, a test may then be made in a few seconds and the crucible remains, of course, absolutely intact. The homogeneity of the crucible may also be determined by this method.

By means of a commutator at *a b*, measurements may be made alternately of the temperature at *e* and of the EMF developed across the crucible when *e* is at this temperature. The commutator may also be so designed as to reverse *e* and *f* if it is desired to make *f* the hot junction.

It is of course essential that the two platinum wires be made of strictly pure platinum. For this purpose, use is made of Heraeus normal thermoelement wire drawn down; this platinum has shown itself to be a standard, uniform product, which is easily controlled by the electric resistance method above mentioned.

The wires are attached at *e* and *f* by the well known arc-soldering method, which consists in making the crucible one terminal of an electric circuit of about 40 volts and a sharpened graphite pencil the other, with a rheostat in series. The operation of soldering consists in drawing a minute arc between pencil and crucible and at the same instant touching the wire to the crucible at this point. The end of the wire is thus fused to the crucibles. With a little practice this operation may be made so that there is hardly any noticeable effect on the appearance of the crucible after the wire is removed.

In the table are given the results of a series of measurements at about 1050° of the EMF of *pure* platinum against "platinum" crucibles of various makes. In figure 2 are shown the isothermal curves, at 900°, 1000° and 1100°C, for iridium content of platinum in terms of EMF against pure platinum. There is also shown the iridium equivalent of the impurities in the crucibles c, h and k of the table, in terms of their stated iridium content.

It will be noted that all impurities are, for convenience, expressed in terms of iridium content. Of particular interest is

SUMMARY OF THERMOELECTRIC TESTS OF PLATINUM CRUCIBLES

1	2	3	4	5	6	7	8	9	
SOURCE OR MAKER	STATED Ir CONTENT	PREVIOUSLY HEATED	TEMPERATURE OF TEST	EMF: Pt VS. CRUCIBLE	EQUIVALENT Ir CONTENT	EMF FROM Pt-Ir CURVE (SEE 2 AND 4)	EMF EXCESS DUE TO Ir OR IMPURITIES	REFERENCE LETTER	REMARKS
	per cent	*hours*	*deg. C.*	Mv.	*per cent*	Mv.	Mv.		
Heraeus	0.0	17	1050	0.00	0.00	0.00	0.00	a	Normal thermo-element Pt
	0.7	heated	1050	2.00	0.70	2.00	0.00	b	"Tiegel platin"
	0.7	0	1050	2.60	0.90	2.00	0.60	c	"Tiegel platin"
	0.2	24	1050	0.63	0.19	0.10	0.53	d	"Tiegel platin" Heraeus
American Platinum Works	0.2	16	1050	1.00	0 35	0.10	0.90	e	"Tiegel platin" Heraeus
	0.5 to 1.5	11	1075	6.60	2.55	1.50 to 4.10	2.50 to 5.10	f	Commercial
	0.5 to 1.5	4	1085	6.40	2.50	1.50	4.90	g	Commercial
	?	0.5	1100	3.50	1.19		3.50	h	Loaned by purchaser
Baker and Company	?	10	1050	6.75	2.72		6.75	i	Commercial
	?	20	1050	6.95	2.78		6.95	j	Commercial
	2.37	0	1030	6.00	2.37	6.00	0.00	k	Special analyzed make
	0.70	12	1050	1.90	0.66	2.05	−0.15	l	Special analyzed make
	refined	0	1040	0.33	0.10		0.33	m	Specially refined
	?	3 yrs.	1100	3.00	1.01		3.00	m	Used 3 years in laboratory.
Johnston Mathey and Company	?	67	1050	0.48	0.15		0.48	n	Best crucible ware
	?	0	1070	0.68	0.23		0.68	o	Best crucible ware
	?	20	1050	0.63	0.22		0.63	p	Best crucible ware
J. Bishop	?	9 mo.*	1100	2.10	0.68		2.10	q	Loaned by purchaser
	?	0.5	1100	2.20	0.72		2.20	r	Loaned by purchaser
	refined	31	1050	0.60	0.21		0.60	s	Specially refined
Quenessen De Belmont, Legendre et Cie. ..	?	10	1050	2.79	0.98		2.79	t	
	?	0	1060	2.80	0.98		2.80	u	
	?	4	1030	1.60	0.56		1.60	v	

* Used continuously nine months.

the comparison of columns 2 and 6, the former giving the stated iridium content (and often accompanied by the statement that there are no other impurities) and the latter giving the iridium content as determined thermoelectrically by experiment and use of figure 2. In several instances, notably for the crucible of normal thermoelement platinum (a) of Heraeus and for Baker's crucible (k) of 2.37 per cent iridium, the stated and found iridium contents agree exactly. On the other hand there is a wide divergence from the supposed and actual iridium content for several of the crucibles. For example, *f* of the American Platinum Works, supposed to contain not over 0.50 to 1.5 per cent irid-

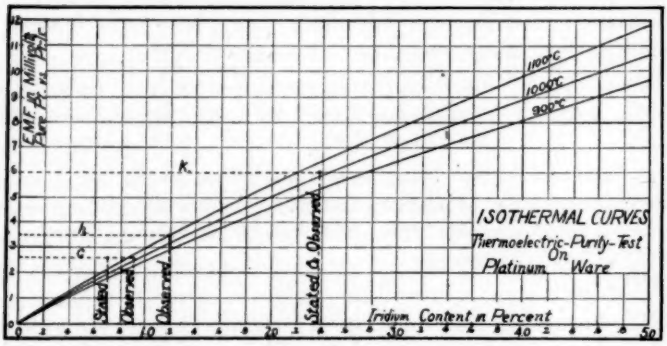

Fig. 2.

ium, actually contains an iridium equivalent of 2.50 per cent; and even in the case of refined, specially refined and best crucible ware, the equivalent iridium content is not inconsiderable. Among the 23 crucibles examined there is but one, *l* of Baker and Company, containing less iridium than stated.

In comparing the stated contents, column 2 of the Table, it should be born in mind that some of these crucibles, excepting perhaps those marked refined or specially refined, may contain iridium which is put or left in the crucible material purposely, usually for the purpose of stiffening, or in the case of commercial ware, because such Pt always carries Ir. The method here

described, however, provides a delicate means of determining whether or not the desired limitation of impurity, expressed in terms of iridium content, and as measured thermoelectrically, has been met by the manufacturer. For the experimental arrangement here given, the amount of impurity is readily determined to 0.01 per cent, and this accuracy could be improved upon if necessary.

The method does not distinguish the various possible impurities from each other but is nevertheless a certain check on the platinum purity.[3] One of the most undesirable impurities often found in commercial platinum ware is iron; this is readily detected by ignition and subsequent washing with hot HCl and applying the usual color test for Fe. Iron, if present in relatively considerable quantity, will also discolor the crucible on ignition.

It would probably be advantageous to substitute rhodium for iridium in platinum crucibles when stiffness is desired and when exact weighings have to be taken before and after ignition, for the reason that rhodium is far less volatile than iridium, and somewhat less so than platinum, although it appears not yet to have been proven that the more volatile metals alloyed in small amounts with platinum retain their volatility independently of the presence of the platinum.

The above described thermoelectric method alone will not distinguish between small amounts of rhodium and iridium, but a combination of the thermoelectric and loss of weight methods might be devised that would be satisfactory. An electric discharge method operated at high temperatures might possibly be made sufficiently selective to differentiate between platinum alloys of iridium and rhodium. There is evidently room for much more work along these lines.

[3] All the metals found associated with platinum, such as palladium, iridium, rhodium, etc., when alloyed with platinum (up to 90 per cent only of palladium) give, at high temperatures, an E. M. F. of the same sign against pure platinum. Therefore there is no ambiguity or balancing one impurity against another.

GEOLOGY.—*A peculiar fault in southwestern New Mexico.*[1] N. H. DARTON, U. S. Geological Survey.

In a detailed study of the geology of Luna County, New Mexico, I have found a very remarkable overthrust fault which causes a sliver of granite to penetrate a mass of limestone. At first sight the relations appeared to indicate an intrusion, but closer inspection showed that the relation was caused by complex faulting.

The region is one of scattered mountain ranges and buttes rising out of wide desert plains or bolsons. Florida Mountain, in which the fault occurs, lies southeast of Deming and is one of the most prominent features in the area. This range consists of pre-Cambrian granite overlain by a succession of sandstone and limestones of Cambrian to late Carboniferous age, with a thick mass of volcanic agglomerate at its northern end. The contact of granite and basal Cambrian sandstone is exposed at various places, showing unmistakable unconformity with well-marked shore-line conditions. Much of the granite is very massive and of coarse texture, similar to the greater part of the pre-Cambrian granite of the Southwest. The range is traversed by numerous faults, many of them of great throw and with planes at various inclinations. The fault to which this paper relates is on the southwestern slope of the range, 18 miles south-southeast of Deming and nearly 2 miles due south of Gym Peak. The limestone mass penetrated by the granite is one of three small wedges overthrust onto granite and considerably isolated by erosion. The limestone contains fossils of the Pennsylvanian series of the Carboniferous. Underlying Silurian and Ordovician limestones and Cambrian sandstone are believed to be faulted out, for their presence a mile or so north apparently precludes the chance of unconformable overlap. The relations at the overthrust are represented in the following sections which show that there was a complex movement of such character that wedges of limestone are partly included in the granite and that a sliver of granite projects through one of them, as shown on a larger scale in the section B.

[1] Published with permission of the Director of the U. S. Geological Survey.

Some of the details of the relations are obscured by talus, but many of the features are clearly exposed, especially the contacts of the included sliver of granite. The latter is red, coarse-grained, and massive, of the sort which constitutes a large part of the range, and while it is greatly broken and crushed it shows no fining of grain such as occurs at igneous contacts. The limestone near the contact is not in the least metamorphosed. It is shattered and brecciated and for a foot or more includes small angular fragments of granite of various sizes, mingled with broken fragments of limestone as if the two materials had been rolled together along many subordinate fault planes. The precise

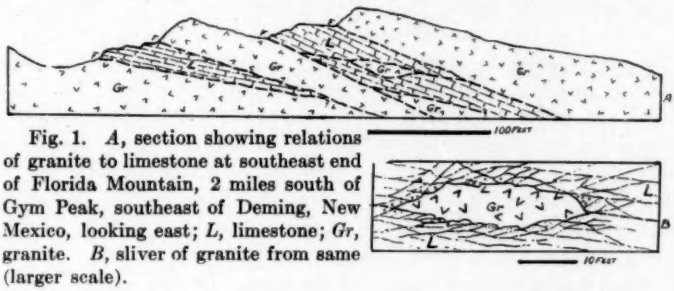

Fig. 1. *A*, section showing relations of granite to limestone at southeast end of Florida Mountain, 2 miles south of Gym Peak, southeast of Deming, New Mexico, looking east; *L*, limestone; *Gr*, granite. *B*, sliver of granite from same (larger scale).

mechanism of the faulting of the included granite sliver cannot be fully ascertained, for erosion has severed the connection on the outcrop side and the mass extends into the ridge on the other side. It is evident, however, that the granite is a wedge-shaped mass between two principal fault planes with many minor ones, along which it was carried forward into the limestone. The latter is one of several large, wedge-shaped bodies overthrust onto the granite by fault planes of low inclination. These faults are similar to one crossing the range a mile north but with planes nearer the horizontal so that erosion has removed much of the block, leaving only a few outlying masses of limestone to indicate the nature of the overthrust.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal, and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

BACTERIOLOGY.—*Pasteurization in bottles and the process of bottling hot pasteurized milk.* S. HENRY AYERS and W. T. JOHNSON, JR. Journal of Infectious Diseases **14:** 217–241. March, 1914.

The investigations show that very satisfactory bacterial reductions may be obtained by pasteurization in bottles for thirty minutes at 145°F. In order to obtain the best results the bottles should be steamed for two minutes before filling with milk. During heating the temperature of the milk should be recorded by a thermometer the bulb of which is one-half inch from the bottom of the bottle. When seal caps are used care must be taken to use only bottles with perfect tops for leaking caps might cause dangerous infections from polluted water. A method is given for detecting leaking caps. The advantages and disadvantages of pasteurization in bottles is discussed.

Experiments were also made on a new process for pasteurization which consists in bottling the pasteurized milk while hot in steamed bottles. It is then proposed to cool the milk by means of blasts of cold air. Excellent bacteriological results were obtained by this process. While the process of cooling by forced air draft was found to be slow as compared with the ordinary methods of cooling, the bacterial content was not affected even when five hours were required to cool the milk from 145° to 50°F.

The authors point out that this process is only in an experimental state and that further experiments are to be made on a commercial scale. L. A. ROGERS.

ZOOLOGY.—*A contribution to the study of the ophiurans of the United States National Museum.* RENÉ KOEHLER. Bulletin 84, U. S. National Museum. Pp. i–vii, 1–173, pls. 1–18. April 9, 1914.

The present work summarizes the results of a study of a large collection of ophiurans chiefly from the West Indies and the southeastern

United States, but including a few from other localities. The richness of the material has enabled the author to describe twenty-four new species and a new genus, *Ophiomisidium*, and to make critical studies of several species which were imperfectly known up to this time.

To make the record complete for the West Indian ophiurans in the National Museum, a list is appended of those species identified many years ago by the Hon. Theodore Lyman, with the localities for each.

MARY J. RATHBUN.

ZOOLOGY.—*Monograph of the shallow-water starfishes of the North Pacific coast from the Arctic Ocean to California.* ADDISON EMERY VERRILL. Harriman Alaska Series, vol. XIV. Smithsonian Institution, Publication 2140. City of Washington, April 30, 1914. Part I: Text. Pp. i–xii, 1–408, text figures 1–16. Part II: Plates. Pls. 1–110.

This, which is the first volume of the Harriman Alaska Series to be published by the Smithsonian Institution, is based on collections from the Harriman Expedition, the Canadian Geological Survey and various museums and individuals. The introduction deals with the richness of the fauna and the food, migrations, larval stages, senses and variations of starfishes. More than half of the systematic part is devoted to the family Asteriidae, for which there is given an analytical table of the genera and species, etc., occurring in the region. Discusses the relations of this and other faunae and closes with a bibliography.

Seventeen new genera and many new species, subspecies and varieties are described. MARY J. RATHBUN.

ZOOLOGY.—*Notes on some specimens of a species of onychophore* (Oroperipatus corradoi) *new to the fauna of Panama.* AUSTIN HOBART CLARK. Smithsonian Miscellaneous Collections **63**[2]: 1, 2. February 21, 1914.

Four specimens of *Oroperipatus corradoi* (Camerano), collected by Mr. James Zetek at Ancon, Panama Canal Zone, are described in detail and a list is given of all the species of onychophores which are known to occur in the Canal Zone. A. H. C.

ZOOLOGY.—*A monograph of the foraminifera of the North Pacific ocean: Part III, Lagenidae.* JOSEPH A. CUSHMAN. Bulletin 71, U. S. National Museum. Pp. i–ix, 1–125, pls. 1–47. December 12, 1913.

The present volume, which is the third of a series dealing with the foraminifera of the North Pacific ocean, relates wholly to members of

the family Lagenidae, distributed among 5 subfamilies and 12 genera, all of these previously recognized. The method of treatment is uniform with that of the preceding parts. Comparatively few species are described as new. W. R. M.

ANTHROPOLOGY.—*Culture of the Ancient Pueblos of the Upper Gila River region, New Mexico and Arizona. Second Museum–Gates expedition.* WALTER HOUGH. Bulletin 87, U. S. National Museum. Pp. i–xiv, 1–139; pls. 1–29; figs. 1–348. February 13, 1914.

This paper is a study of the material collected by the second Museum-Gates expedition on the upper Blue, San Francisco, and Tularosa rivers, New Mexico and Arizona.

The expedition was singularly fortunate in collecting a large series of articles from a ceremonial cave on Blue River, Arizona, and from a cave on Tularosa River which had been filled with debris from habitations built across its opening. Excavations were made also in several open air Pueblos, notably a large group at Blue P. O., Arizona. In this way a rather wide view of the culture of this region was obtained. A great many articles relating to natural history were secured also, and the discussion of these forms the first chapter of the book. Following this the objects of stone, bone, and shell, of pottery, of wood, and of textiles, and religious objects are described. The concluding section describes a number of mummied human remains from the ruins.

The Pueblos in this region have evidently been extinct for many centuries. Coronado traversed this region in 1540 and found no inhabitants. The culture here was mainly homogeneous with the ancient culture of other parts of the Pueblo region, some resemblances and differences being noticeable. Perhaps the culture was little higher than that of the northern area in certain respects.

Wherever it was possible in discussing religious objects these are correlated with surviving customs among the modern tribes. This branch of the work is necessarily very incomplete, since there is a deplorable lack of information with regard to the existing Pueblos. Nevertheless such comparisons as can be made show a surprising continuity of religious customs and paraphernalia down to the present.

W. H.

REFERENCES

Under this heading it is proposed to include, by author, title, and citation, references to all scientific papers published in or emanating from Washington. It is requested that authors coöperate with the editors by submitting titles promptly, following the style used below. These references are not intended to replace the more extended abstracts published elsewhere in this JOURNAL.

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STERRETT, W. D. *Forest management of loblolly pine in Delaware, Maryland, and Virginia.* Bulletin of the U. S. Department of Agriculture, No. 11. Pp. 1–59. January 23, 1914.

WILLIAMSON, A. W. *Cottonwood in the Mississippi valley.* Bulletin of the U. S. Department of Agriculture, No. 24. Pp. 1–62. December 31, 1913. (Gives methods of planting, rate of growth, and commercial uses of the cottonwood, *Populus deltoides.*—C. S. S.)

ZON, R. *Balsam fir.* Bulletin of the U. S. Department of Agriculture, No. 55. Pp. 1–68. March 25, 1914. (An account of the distribution of *Abies balsamea,* its economic importance, methods of lumbering, structure of the wood and rate of growth, with data on yield, volume and weight of lumber and wood.—C. S. S.)

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE GEOLOGICAL SOCIETY OF WASHINGTON

The 282d meeting was held at the Cosmos Club, March 25, 1914.

INFORMAL COMMUNICATIONS

Reactions of nickel arsenides with silver salts: CHASE PALMER.

An occurrence of chrysotile asbestos at Ash Creek, 35 miles northeast of Globe, Arizona: J. S. DILLER.

Concave exfoliation: F. E. MATTHES. Concave exfoliation in massive granite under the bed of Yosemite Creek, in the Sierra Nevada, was described as an illustration of the diversity of form which shells resulting from superficial exfoliation may exhibit. Such shells, far from being always spherical may be plane, or even concave, according to the configuration of the surface upon which they develop.

Radial barite concretions from the Cretaceous of southeastern Montana: C. A. BONINE.

REGULAR PROGRAM

Stratigraphy of the Red Beds in New Mexico (illustrated): N. H. DARTON. In this communication there was presented an outline of the results of study of the central and western parts of the Red Beds area in New Mexico during the past summer. The investigation was primarily a search for evidence which might lead to the discovery of potash deposits in the Red Beds, and this part of the work is not yet finished. Close attention was given to the stratigraphy, especially as to relations and succession of gypsum deposits and other desiccation products, with a view to determining areas in which chemical deposition had continued longest. Much new light was obtained on the relations and development of a great series of alternating limestones and gypsum deposits, the San Andreas limestone of Lee, which separates a thick lower formation of red beds from an upper formation of red beds in a wide area in central New Mexico. Some attention was given to the separation of the Triassic portion of the Red Beds in part of the area. Evidence was obtained as to the possible extension of Jurassic rocks into the region, and the probable Morrison formation was traced far to the south and southwest in New Mexico.

Moraine Dome and the moraines of the Little Yosemite Valley (illustrated): F. E. MATTHES. Moraine Dome is a low granite dome on the north side of the Little Yosemite Valley, in California, of interest chiefly for the moraines and other glacial features associated with it. The ice of the last glacial epoch, when at its highest, split upon the northeast end of the dome and pushed a short lobe through the saddle to the north, as is shown by the successive moraines doubling around the eminence.

The course of these moraines throughout exhibits an independence of the trough edge, suggesting strongly that the formation of the trough was not the work wholly of the ice invasion represented by the moraines in question. The trough evidently existed previous to the advent of the later ice and was only modified by the latter. In this regard, the indications of the moraines of the Little Yosemite Valley are similar to those in other localities in the Yosemite region. Accordingly valley troughs hewn one within the other are not to be correlated with separate ice invasions, but appear to have been traversed and enlarged by each of these in succession.

Moraine Dome is of interest, further, in that it affords approximate measures of the depth of denudation suffered by its mass since the later as well as the earlier ice epochs. Old surface shells preserved from disintegration by the uppermost moraine of the later ice, and recently uncovered by rain wash, show that since the moraine was deposited a thickness of about 3 feet of granite has disappeared from the surface of the dome.

On the crown of Moraine Dome a vertical dike of aplite has weathered out in the form of a little wall, eight feet high. Several large erratics near by, composed of a coarsely porphyritic granite from the crestal portion of the Sierra Nevada, one of them mounted on a pedestal about 4 feet high, show beyond doubt that the dome was overridden by the earlier ice. It is clear, therefore, that the aplite dike has weathered out since the retreat of the earlier ice, and that its height may be taken as an approximate measure of the depth to which the dome has been denuded since that date.

The occurrence of carnotite in eastern Pennsylvania: EDGAR T. WHERRY. Carnotite occurs near Mauch Chunk, Carbon County, Pennsylvania, as an impregnation in a conglomerate. Analysis shows it to be high in potassium and low in calcium, the uranium and vanadium showing the usual 1:1 ratio. The features of the rock indicate that the last two metals have accumulated by local concentration of minerals containing them during sedimentation, rather than by precipitation from solution, which has been thought to account best for the features of the Colorado and Utah deposits. Investigation of the commercial value of the deposit is now in progress.

The 283rd meeting was held at the Cosmos Club, April 8, 1914.

INFORMAL COMMUNICATIONS

Correlation of the Hawthorn formation: T. WAYLAND VAUGHAN and C. WYTHE COOKE, presented by Mr. Vaughan. (See this JOURNAL, **4**: 250. May 19, 1914.)

Occurrence of the mineral hisengerite in central Idaho: D. F. HEWETT.

REGULAR PROGRAM

Petrographic evidence on the origin of the Catahoula sandstone: M. I. GOLDMAN. The object of the study was to find what lines of evidence are available for throwing light on the origin of a quartz sandstone with no striking peculiarities. Most of the determinations depended

on the fact that the sandstone has an opaline cement which could be decomposed by boiling with KOH.

The features observed and their interpretation were as follows:

1. Size: Although there is a marked predominance of 0.5 to 0.25 mm. grains, it is not as pronounced as in typical beach sand, resembling rather wind blown sand such as seems to be produced by the strong winds of the tropics.

2. Degree of rounding: Some grains show wonderfully perfect rounding, thus suggesting wind action.

3. Lower limit of rounding: This is the essential factor in rounding, since it is in this that the action of wind and water are believed to differ. The smallest well rounded grains found measure 0.035 mm. diam. This corresponds to the lowest limit found by Fruh in some Pampas soil and is therefore believed to indicate aeolian origin, though the lowest limit for water rounding is not known.

4. Proportion of rounded grains: This is low (28.7 per cent) and in view of the perfect rounding of some of the grains is taken to indicate that fresh angular material was constantly added, which would correspond to the conditions in an arid region.

5. Weathering of the feldspars: Many of these seem remarkably fresh, suggesting the mechanical disintegration of an arid region.

6. Proportion of weathered feldspars: About half are weathered, which, according to Machie's studies, is too much for an arid region, but this condition may have been produced after deposition.

7. Proportion of different species of feldspar: Orthoclase 85 per cent, microcline 13 per cent, plagioclase 2 per cent. The low plagioclase suggests conditions of humid weathering which as stated under (6) may have been subsequent to deposition.

8. Ratio of feldspar to quartz: Feldspar forms 39 per cent of the mass, which is a high percentage for sandstones and like (4) suggests constant addition of fresh material as under arid conditions. It also is evidence against the production of the sizing by beach waves and in favor of wind.

9. Proportion of heavy minerals: In the portion between .05 mm. and 0.25 mm. diameter the heavy minerals amount to 1.1 per cent. This is very low for aqueous deposition, high for a mature desert dune, but might correspond to an arid region where the supply of fresh material is kept up.

10. Species of heavy minerals: The dominant heavy minerals are magnetite and zircon. Zircon is a mineral very resistant to alteration agencies, and magnetite may also be. Practical absence of epidote and chlorite indicates arid conditions.

11. Ratios of heavy minerals to each other: The insignificant quantity of fissile minerals like the micas and ferromagnesian minerals strongly indicates arid conditions.

12. Bedding: Absence of thin bedding indicates rapid accumulation by wind or water currents.

13. Arrangement of fossils: (a) Curled leaves and prints arranged at random point to burial by wind, (b) bunches of leaves fairly flat and

parallel but not on one plane indicate quiet bodies of water into which sand was blown.

14. Clay galls: Clay galls are a characteristic product of a sandy region with temporary bodies of water.

15. Pore space, or packing: The Catahoula sandstone appears loosely packed. The evidence is still very uncertain, but this seems to correspond rather with beach and dune sands.

16. Fossil evidence: The plants which are (according to E. W. Berry) nutmeg, date palm, and palm (unidentified) indicate a tropical coast. Bones of camel and rhinoceros, found near by in the same formation, also indicate a warm climate.

Conclusion: The weight of evidence is for an arid, tropical, sandy region with permanent or temporary bodies of water.

The probable mode of origin of the Lewis overthrust: M. R. CAMPBELL. No abstract.

Auriferous pocket deposits of the Klamath Mountains, California: H. G. FERGUSON. No abstract.

The 284th meeting was held at the Cosmos Club, April 22, 1914.

INFORMAL COMMUNICATIONS

Origin and mode of formation of magmatic gases: STANISLAS MEUNIER, read by C. N. Fenner. (See this JOURNAL, **4**: 213. May 4, 1914.)

So-called waterlaid loess of the central United States: E. W. SHAW. Photographs and specimens of stratified loess from southwestern Kentucky and Yazoo City and Edwards, Mississippi, were exhibited. Much of the stratified loess which has been reported appears to be some other material, though some of it has been derived by wash from nearby outcrops of loess. For example, the stratified loess reported from southwestern Indiana appeared to the speaker to consist of a stream terrace deposit, some windblown sand and some true unstratified loess. However, true loess is, in rare instances, really stratified. The stratification is of a somewhat peculiar type, apparently not involving variations in size of grain. The bedding planes are parallel to the top and base of the deposits and are marked by very thin dark bands which seem to consist of carbonaceous material and are probably the remains of layers of vegetable material, perhaps forest litter developed at times when loess deposition was interrupted, or at least unusually slow. The facts that the stratification does not involve sorting of the component grains, and that it is not horizontal, but parallel to the present and pre-loess surfaces, seems to indicate that even where stratified the loess is not a water-laid deposit. Indeed, it seems surprising that the loess, if wind deposited, does not show more general stratification of this nature because of the annual fall of forest leaves, and other interruptions in deposition.

REGULAR PROGRAM

The characteristics of the Mississippi delta in the light of some observations on Old World deltas: E. W. Shaw. Certain phenomena, par-

ticularly irregular subsidence on land and the upheavals off shore known as mud lumps, suggest that the Mississippi delta is affected by internal flowage, and in the hope of obtaining important side lights on this and other problems a brief examination has recently been made of many large and small deltas of Europe, northern Africa, and western Asia. The progress made in understanding the Mississippi delta was, however, through the observation of dissimilar, rather than similar characters, for each delta seems to be built on individual specifications. The Mississippi delta appears to be unique in the rapidity of its growth, in the fineness and arrangement of the materials composing it, and in other characters which seem related to these, such as the extreme development of the bird foot form, the narrowness, depth, and stability of its stream channels, and a condition of unstable equilibrium.

The stability of a delta appears to depend principally on its thickness, the slope of its front, the proportion of sand in the river's sediment, the extent to which this sediment is washed by the sea or lake, the rate of growth, and the degree to which the fine watery sediment is separated into layers of wide extent. In all characters favoring instability the Mississippi delta seems to lead. The thickness is thousands of feet. The front, though not steeper than that of many sand deltas, is very steep for a mud delta, and might be steeper were it not for flowage. The river delivers to the sea relatively little sand, and most of that is brought at times of high water. The sea does not sort or carry away much of the sediment, so that the delta grows rapidly and layers of sandy silt corresponding to high stages of the river are separated by layers consisting of soft flocculated clay and other fine watery material. All these factors conduce to fluidity.

The fishes of the Lahontan drainage system of Nevada and their relation to the geology of the region: JOHN OTTERBEIN SNYDER. A considerable part of Nevada and the eastern slopes of the Sierra Nevada of California are drained by rivers, the waters of which do not reach the ocean but ultimately find their way into large lakes where the inflow is balanced by evaporation. The waters of some of these lakes are so charged with mineral salts as to be practically lifeless, while others, Pyramid and Winnemucca lakes, for example, fairly teem with fishes. The more recent geological history of this region has been worked out and narrated in a masterly way by Israel Cook Russell.[1] His account begins with the Quaternary times, when Lake Lahontan covered a large area with a maximum depth of more than 880 feet, and continues down to the present, when nothing is left of the ancient lake but its desiccated remains scattered here and there over a rock-bound waste of desert sands. Two of Russell's conclusions are of particular interest when viewed in connection with the results of an investigation of the fish fauna of the system: First, that the lake had no outlet; and, sec-

[1] Russell, Israel Cook. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada: U. S. Geol. Surv. Monograph No. 11, Washington. 1885.

ond, that its desiccation lately became complete and remained so to within the last three hundred years. Russell arrived at the first conclusion through a study of present conditions and a careful reconnaissance of the rim of the basin. In this he is supported by the ichthyology of the region, as nearly all of the species are indigenous, thus indicating long isolation. He was forced to adopt the second hypothesis to account for the comparatively fresh condition of the waters of Pyramid Lake. In this he receives no support from a study of the fishes, but on the contrary the facts thus derived point distinctly to the presumption that the present Pyramid and the ancient Lahontan lakes have been continuous since Quaternary times and that their waters have been constantly fresh enough to support animal and plant life.

The upper Cretaceous formations of western New Mexico and their relations to the underlying rocks: D. E. WINCHESTER. In the area surrounding the Zuni Mountains in western New Mexico, the Upper Cretaceous is represented by the Mesaverde, Mancos, and Dakota formations, with the latter resting unconformably on older strata. In a section of these formations near the Tres Hermanos Buttes, southeast of the Zuni Mountains, the Dakota is represented by a single conglomeratic sandstone or quartzite bed, varying in thickness from 1 to 40 feet. The Mancos (1800 feet thick) is more than 60 per cent sandstone and includes four massive, persistent sandstone beds which stand out as prominent cliffs wherever exposed. In its type locality, 200 miles to the north, the Mancos is entirely shale. Between these two localities near Gallup, New Mexico, there is a large amount of drab, fissile shale, but the section is still predominantly sandy. The Mesaverde formation in the Tres Hermanos section contains no persistent massive sandstone, as it does in its type locality 200 miles to the north. In New Mexico both the Mancos and the Mesaverde formations are coal-bearing, while in their type locality in southeastern Colorado, only the Mesaverde contains coal. Lithologically, then, there is a marked change especially in the Mancos between the area about the Zuni Mountains and the type locality to the north, indicating, as has been suggested by W. T. Lee, that the mountains furnishing the sediments were located to the south of both sections.

The unconformity between the Upper Cretaceous and underlying sediments is very marked. At Zuni, on the west side of the Zuni Mountains, the Dakota rests on top of 475 feet of Zuni sandstone, while at Atarque, 23 miles south, there is only about 75 feet of Zuni sandstone beneath the Dakota. On the east side of the mountains conditions are similar, with about 450 feet of Zuni sandstone beneath the Dakota at Acoma and the sandstone entirely absent near Tres Hermanos Buttes, 22 miles south. If the Zuni sandstone is to be correlated, as apparently it should be, with the La Plata sandstone of southwestern Colorado, pre-Dakota erosion has also removed all, or nearly all, of the McElmo formation (500 to 600 feet) in the area surrounding the Zuni Mountains.

FRANK L. HESS, *Secretary.*

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